Inverse-Scattering Theory and the Density Perturbations from Inflation

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A wealth of data drives much of the current activity in cosmology. Amongst these data, perhaps the cleanest signal from the primordial universe is the power spectrum of density fluctuations, which is obtained from observations of fluctuations in the microwave background sky and from observations of the large-scale clustering of matter. Especially in the case of microwave background observations, the observed fluctuations give direct information on the "initial conditions" for the density perturbations that manifest in the gravitational clustering of matter in the universe.

In an inflationary universe, these initial density perturbations arise as a relic of quantum fluctuations from the very earliest times. The inflationary evolution causes these modes to grow in amplitude, with a time-evolution that is determined completely by the evolution of the space-time geometry, encoded in the scale-factor $a(t)$. This evolution imprints a signature of the inflationary evolution on the spectrum of modes. Therefore, structure in the mode spectrum can be directly related to the evolution of $a(t)$ and hence to the nature of the stress-energy which drives inflation. Because the nature of inflation is quite mysterious, information of this sort is very important for cosmology.

Recently, we have developed a completely new method for understanding the primordial density fluctuations in the universe [1]. Our new approach relies on inverse methods, specifically inverse scattering theory, to work backwards from the fluctuations observed today. This is in contrast with previous work in the field, which is based on model calculations. Our method extracts the information in the data that is model-independent and nonparametric and thus provides a completely general framework for understanding the origin of primordial fluctuations in the universe.

Figure 1 illustrates the simplest application of our ideas, showing the asymptotic reconstruction of the "effective potential" for density waves as a function of time in the very early universe, for example, time-evolution.

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[1] S. Habib, et al., *Phys. Rev. Lett.* **94**, 061303 (2005).

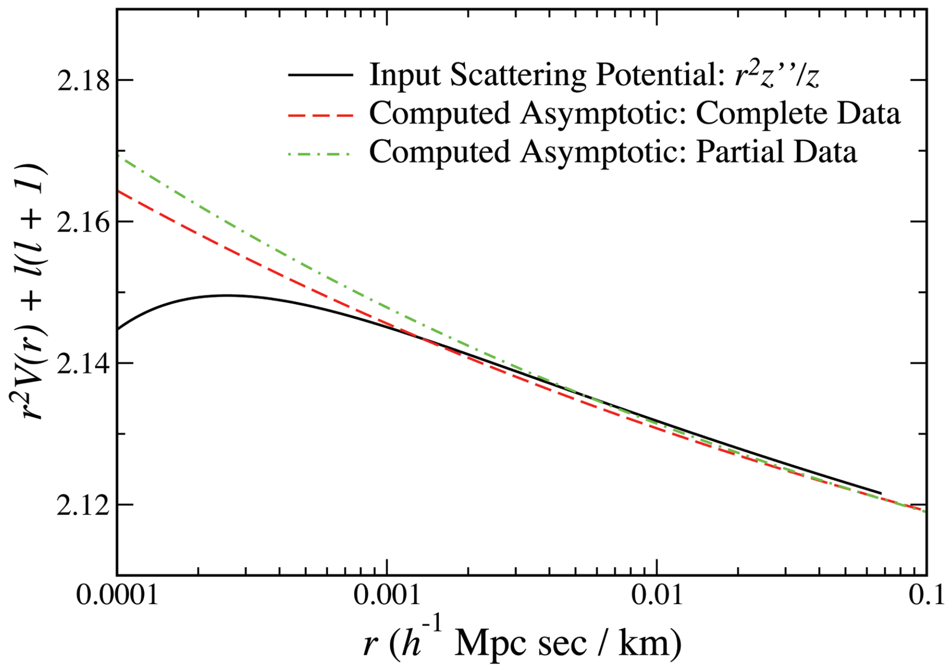

Fig. 1.
Asymptotic comparison of reconstructed scattering potential to the input. The input was tabulated during the initial computation of the power spectrum for the assumed evolution.